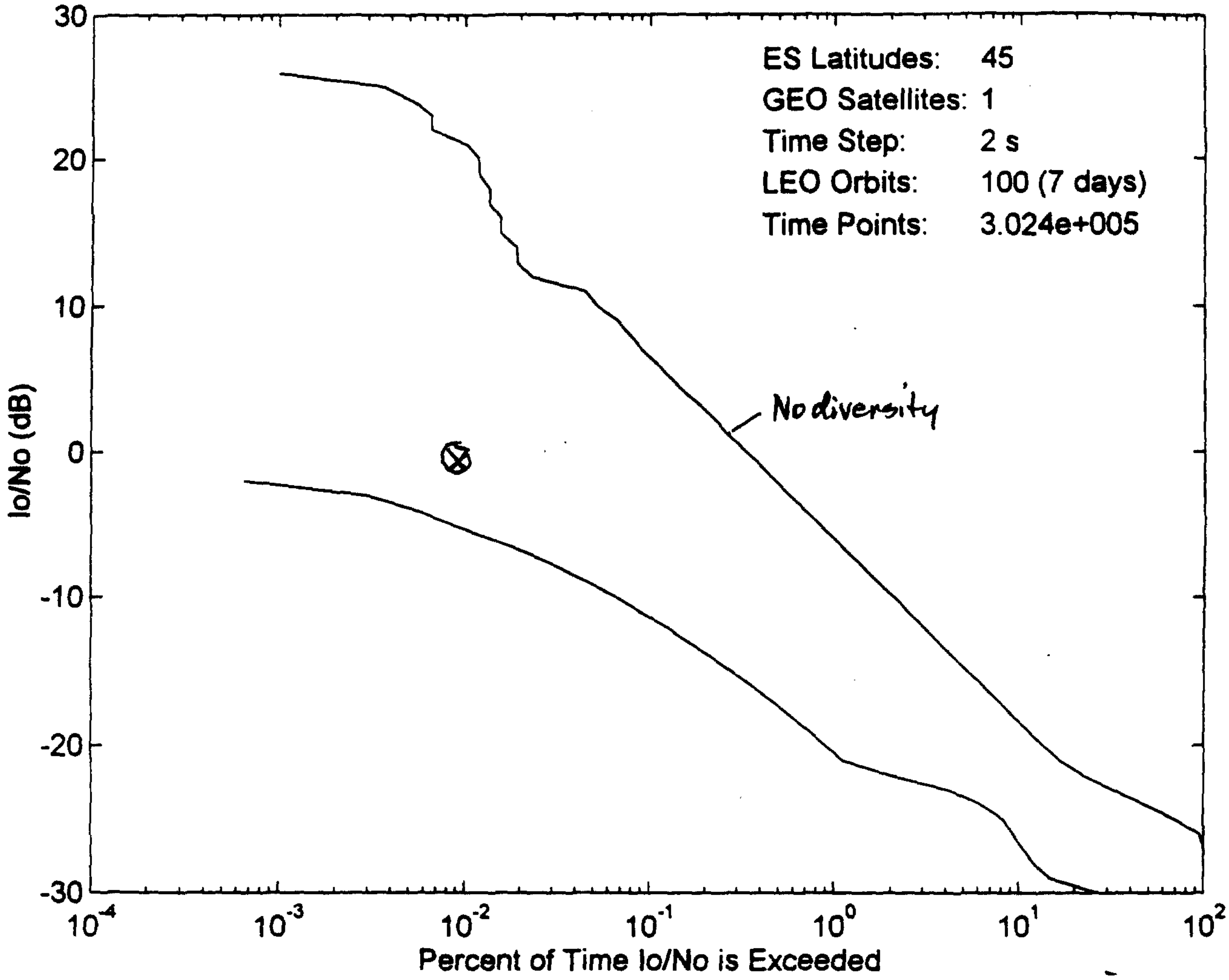
Figure 3d - SPACEWAY into IRIDIUM Uplink Using Satellite Diversity



at lat >45 multiple sats results in big improvement

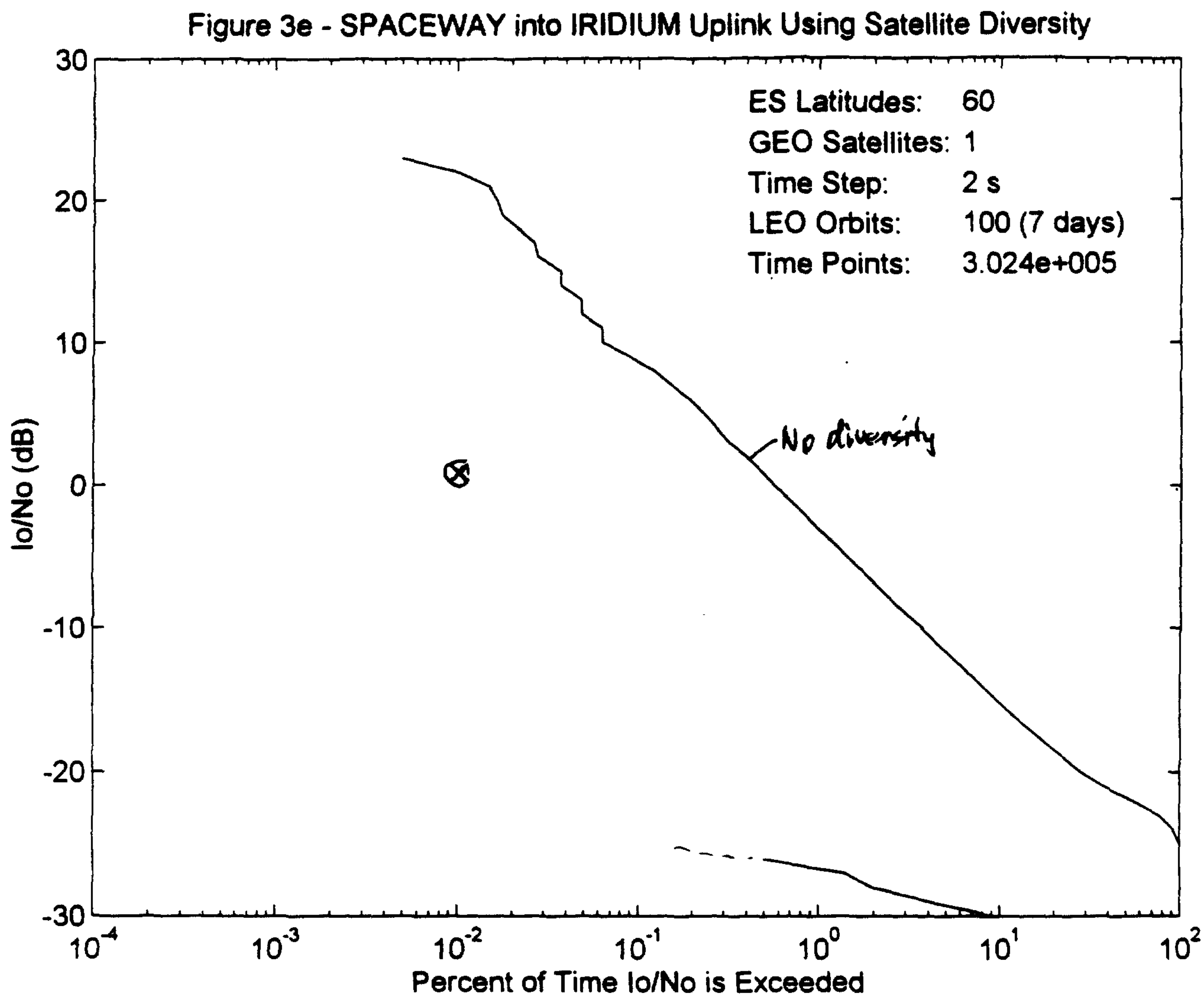


Figure 3e - SPACEWAY into IRIDIUM Uplink Using Satellite Diversity
ES Latitudes: 60
GEO Satellites: 1
Time Step: 2 s
LEO Orbits: 100 (7 days)
Time Points: 3.024e+005
No diversity
Io/No (dB)
30
20
10
0
-10
-20
-30
10^{-4}
10^{-3}
10^{-2}
10^{-1}
10^{0}
10^{1}
10^{2}
Percent of Time Io/No is Exceeded

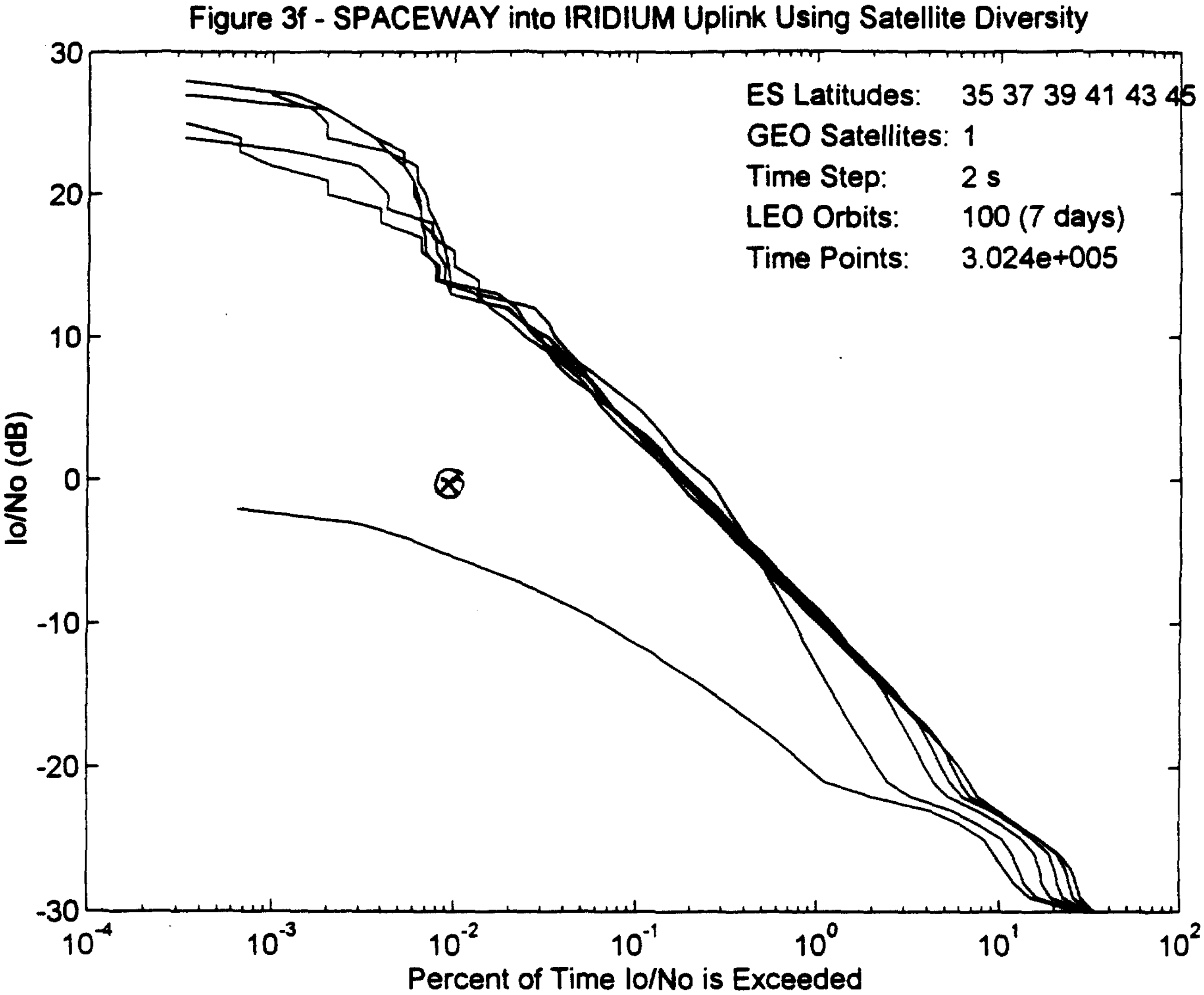


Figure 3f - SPACEWAY into IRIDIUM Uplink Using Satellite Diversity
ES Latitudes: 35 37 39 41 43 45
GEO Satellites: 1
Time Step: 2 s
LEO Orbits: 100 (7 days)
Time Points: 3.024e+005
Io/No (dB)
30
20
10
0
-10
-20
-30
10^-4
10^-3
10^-2
10^-1
10^0
10^1
10^2
Percent of Time Io/No is Exceeded

Figure 4a - SPACEWAY into IRIDIUM Uplink Using Site Diversity

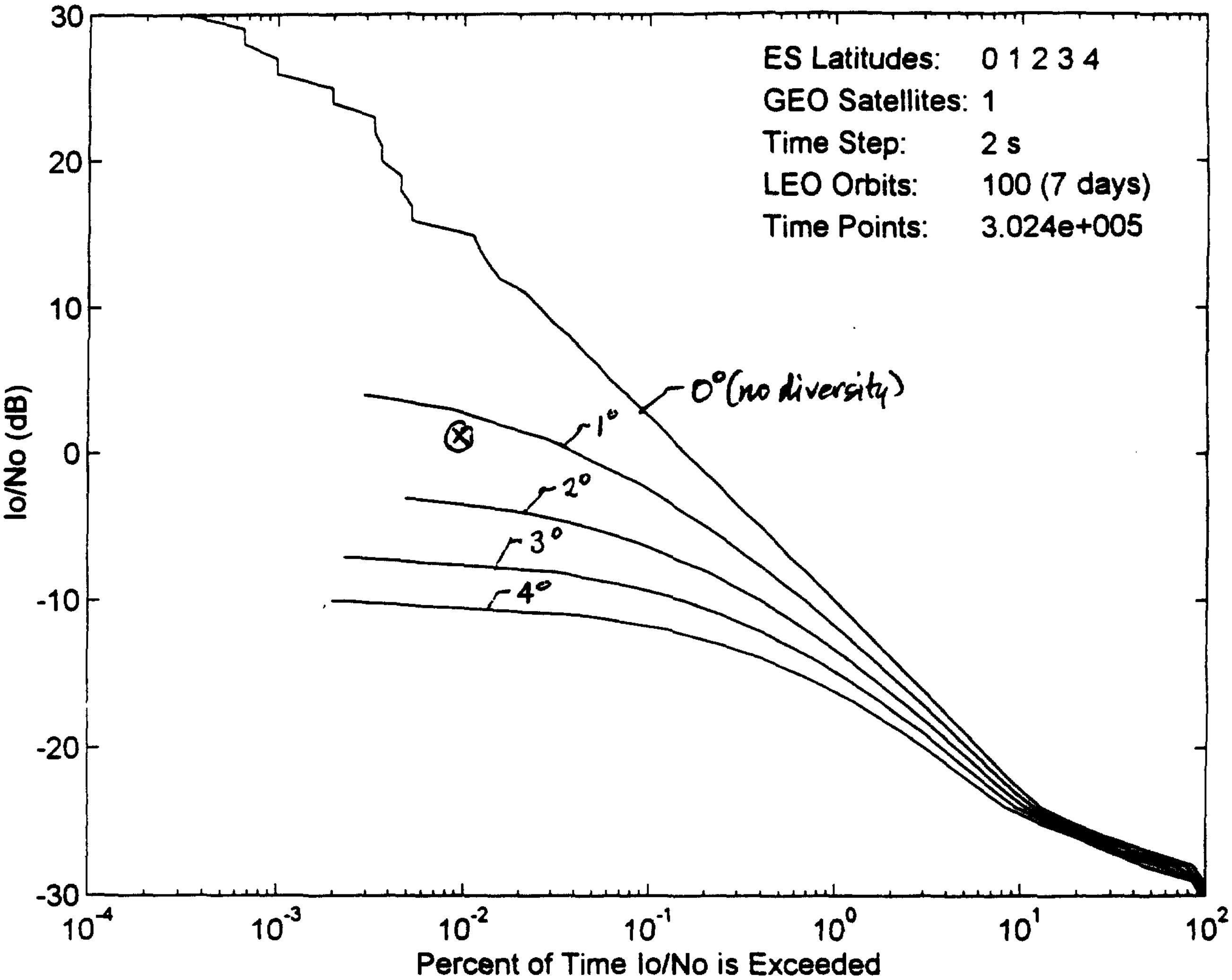
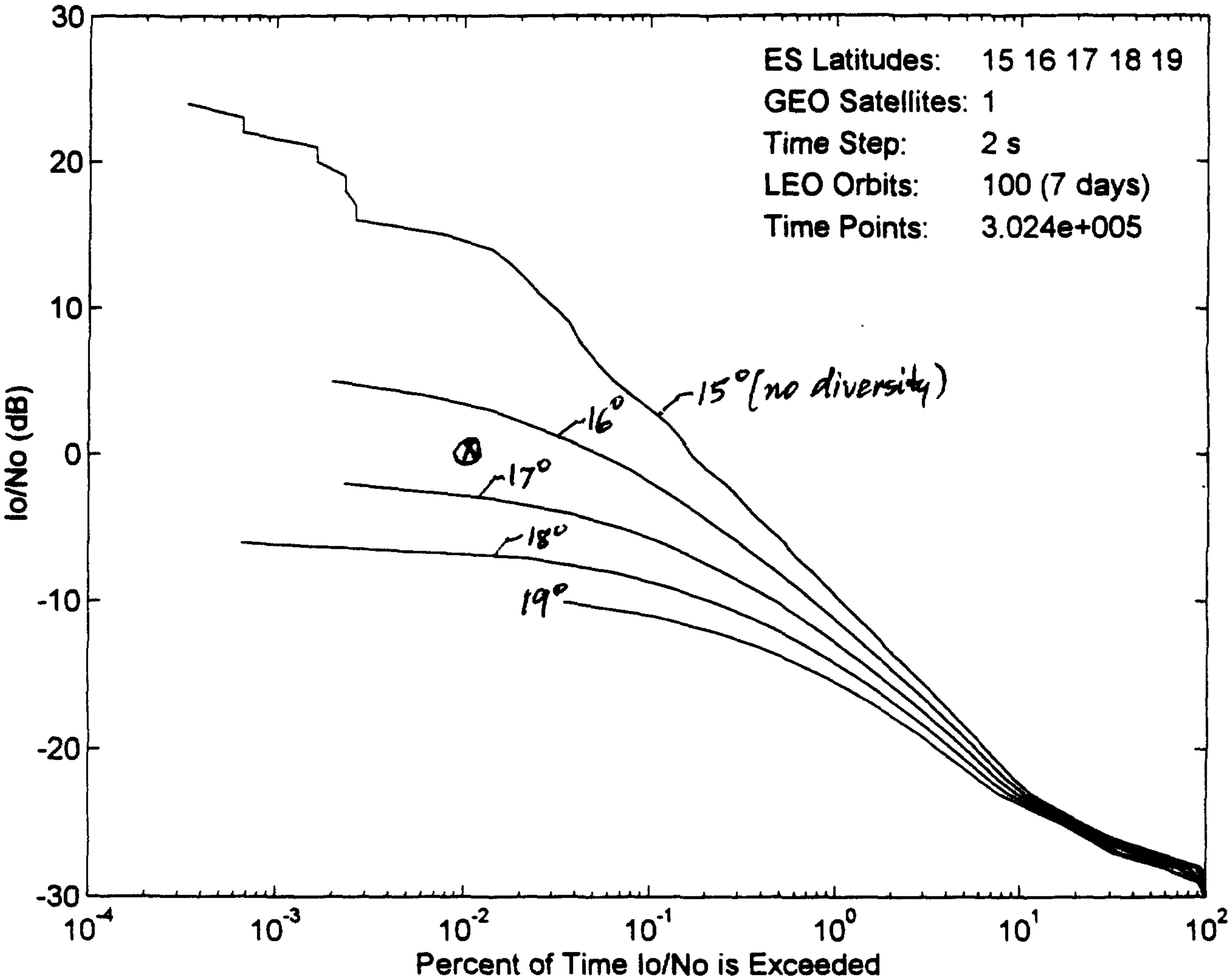


Figure 4b - SPACEWAY into IRIDIUM Uplink Using Site Diversity



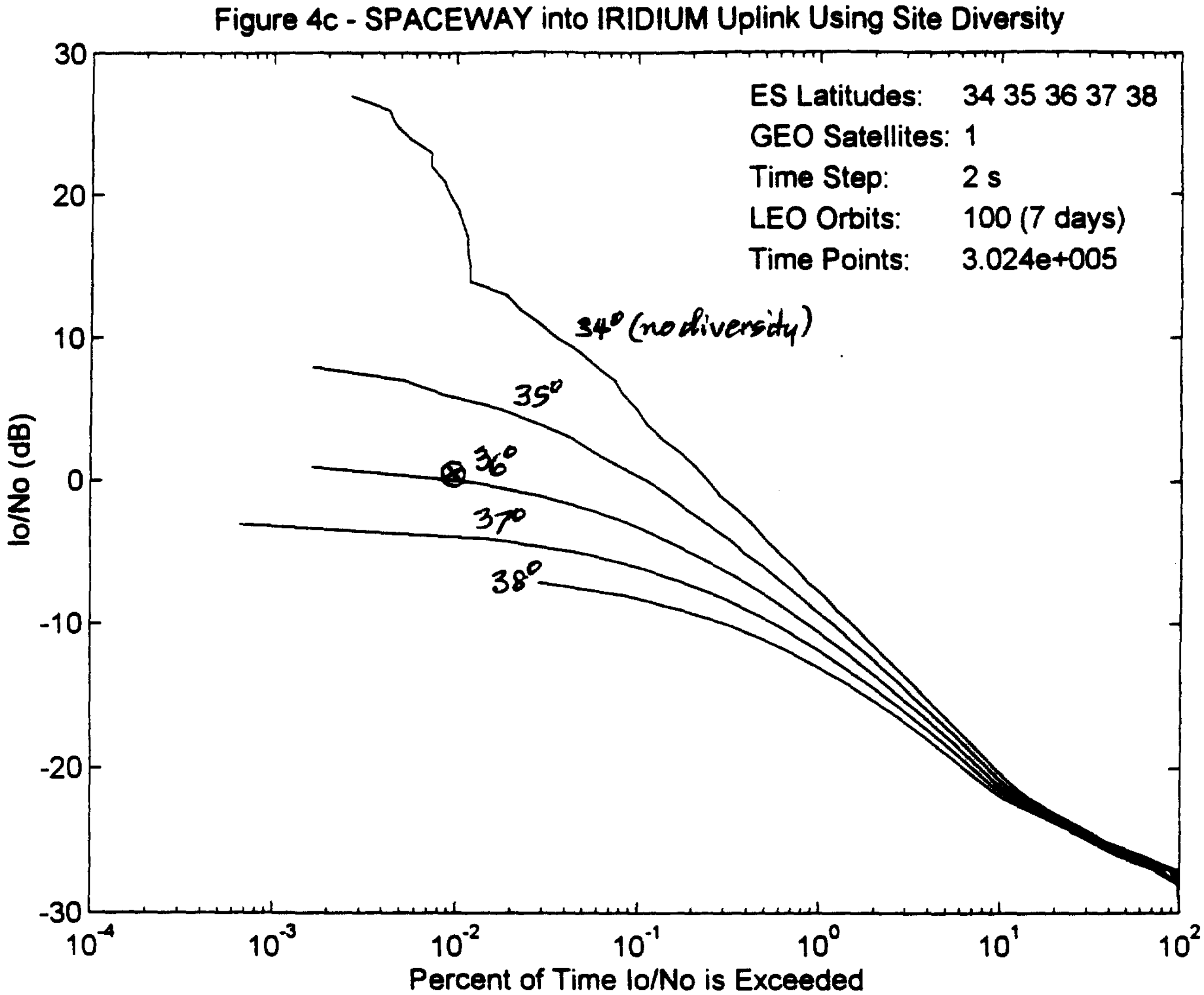


Figure 4c - SPACEWAY into IRIDIUM Uplink Using Site Diversity
ES Latitudes: 34 35 36 37 38
GEO Satellites: 1
Time Step: 2 s
LEO Orbits: 100 (7 days)
Time Points: 3.024e+005
34° (no diversity)
35°
36°
37°
38°
Io/No (dB)
Percent of Time Io/No is Exceeded

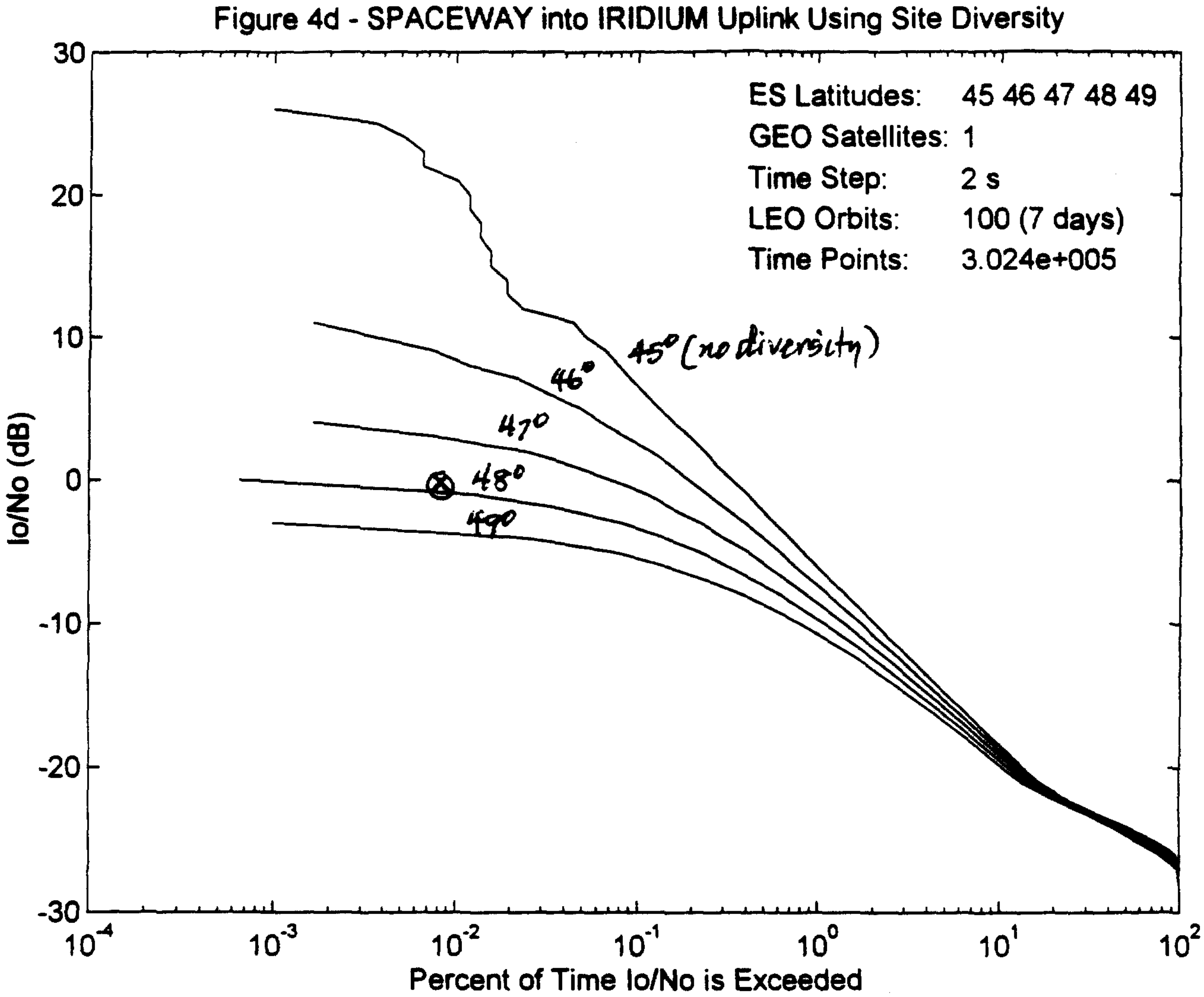


Figure 4d - SPACEWAY into IRIDIUM Uplink Using Site Diversity
ES Latitudes: 45 46 47 48 49
GEO Satellites: 1
Time Step: 2 s
LEO Orbits: 100 (7 days)
Time Points: 3.024e+005
45° (no diversity)
46°
47°
48°
49°
Io/No (dB)
30
20
10
0
-10
-20
-30
10^-4
10^-3
10^-2
10^-1
10^0
10^1
10^2
Percent of Time Io/No is Exceeded

Figure 4e - SPACEWAY into IRIDIUM Uplink Using Site Diversity

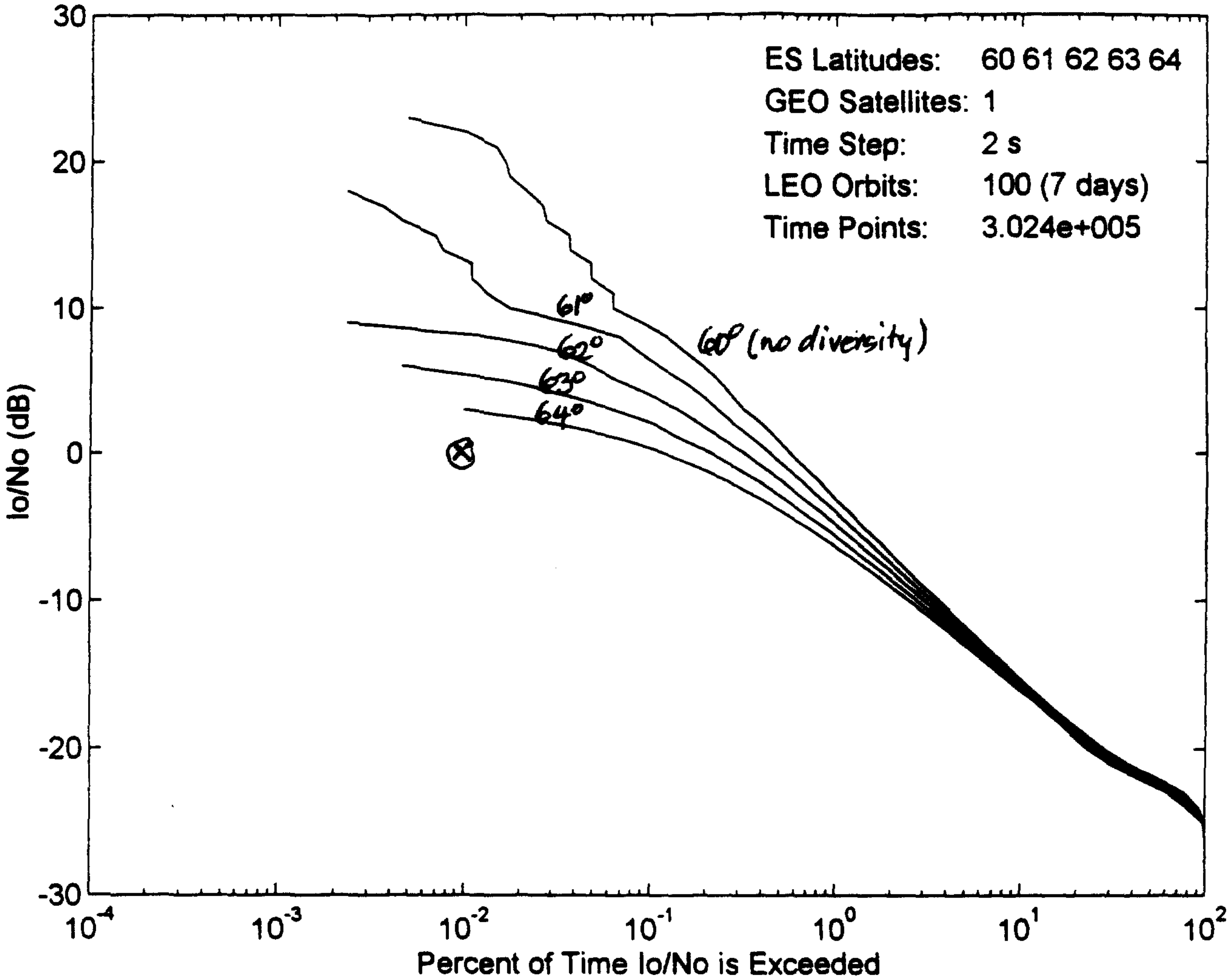


Figure 5a - SPACEWAY into IRIDIUM Uplink Using Path Diversity

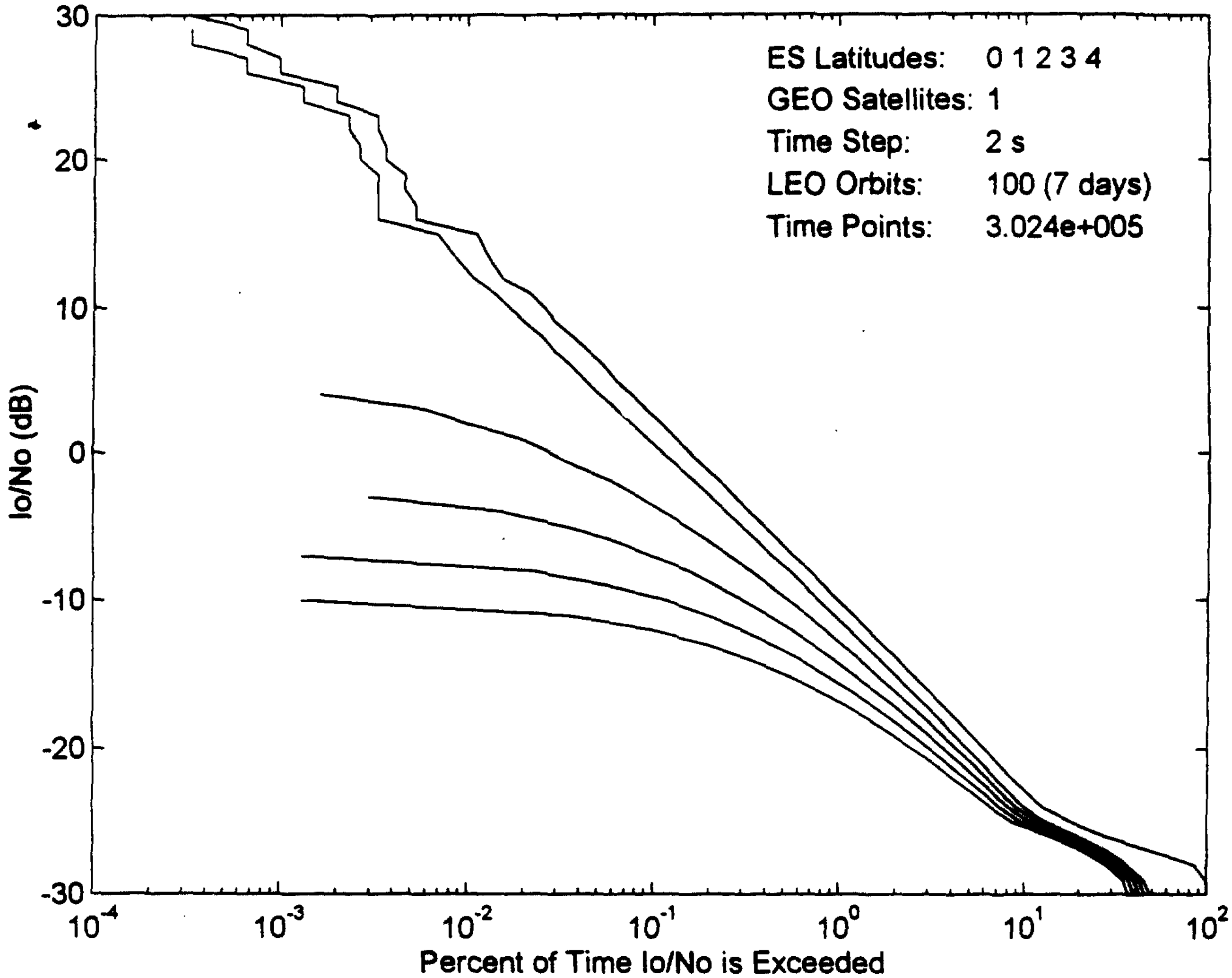


Figure 5b - SPACEWAY into IRIDIUM Uplink Using Path Diversity

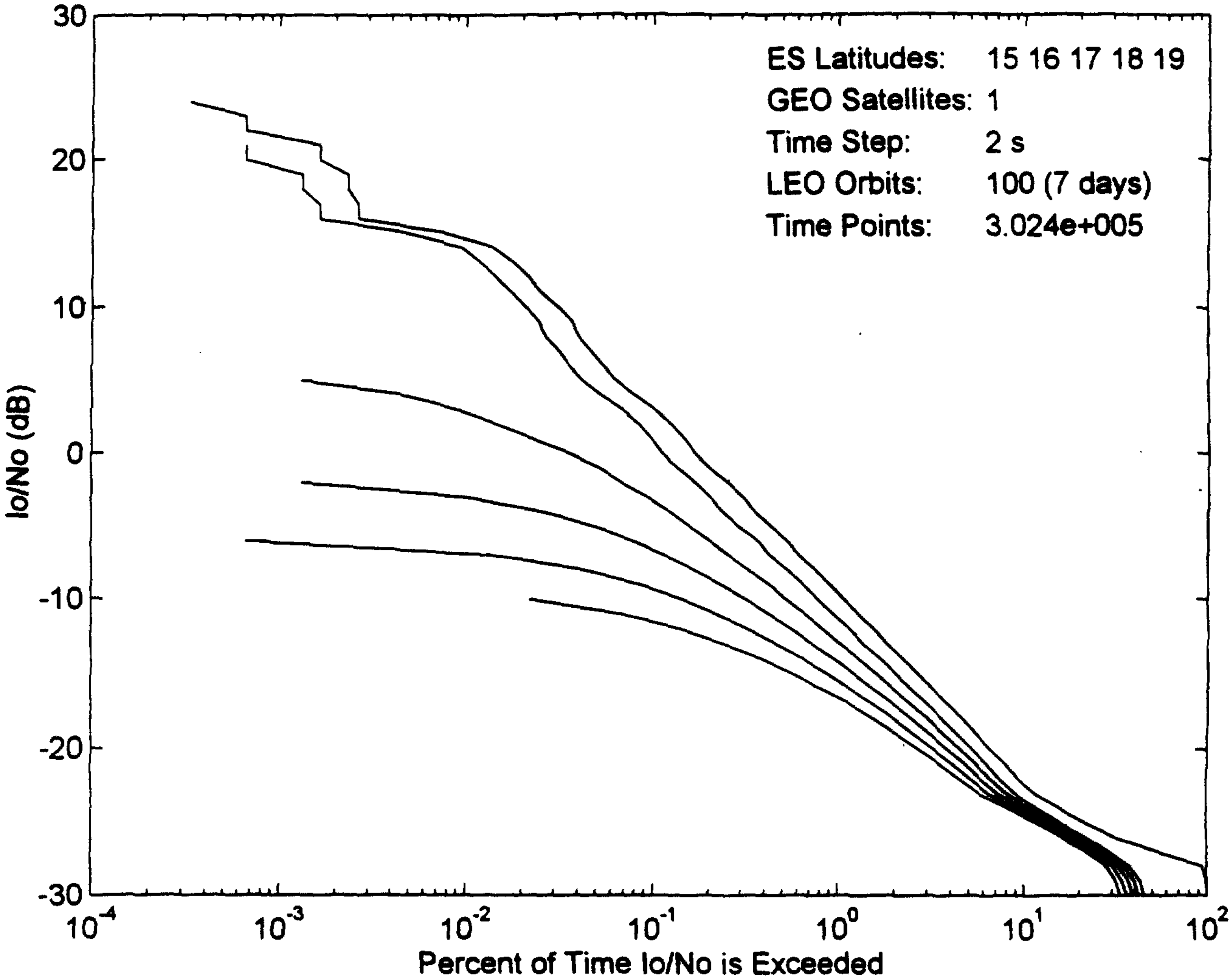


Figure 5c - SPACEWAY into IRIDIUM Uplink Using Path Diversity

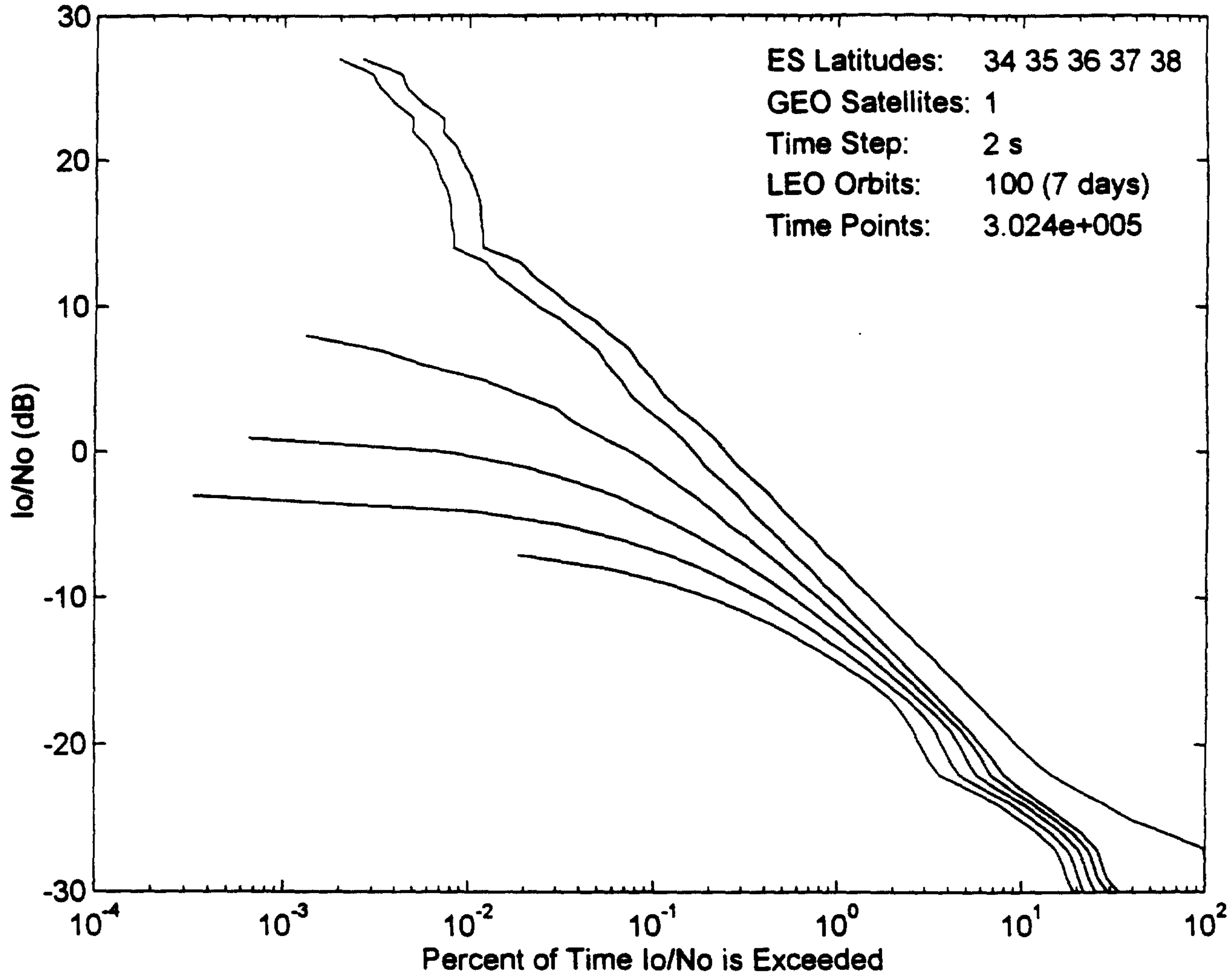
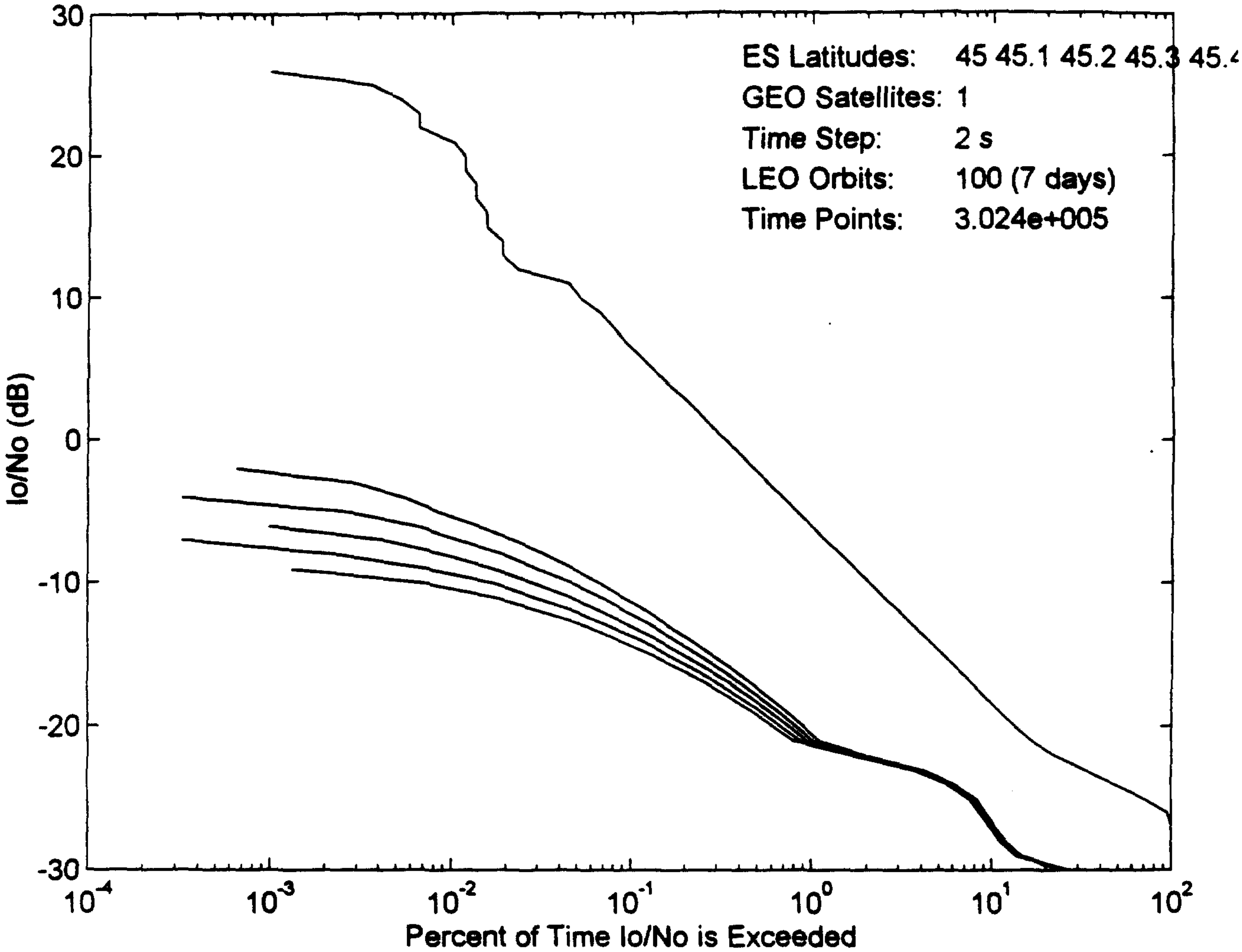


Figure 5d - SPACEWAY into IRIDIUM Uplink Using Path Diversity



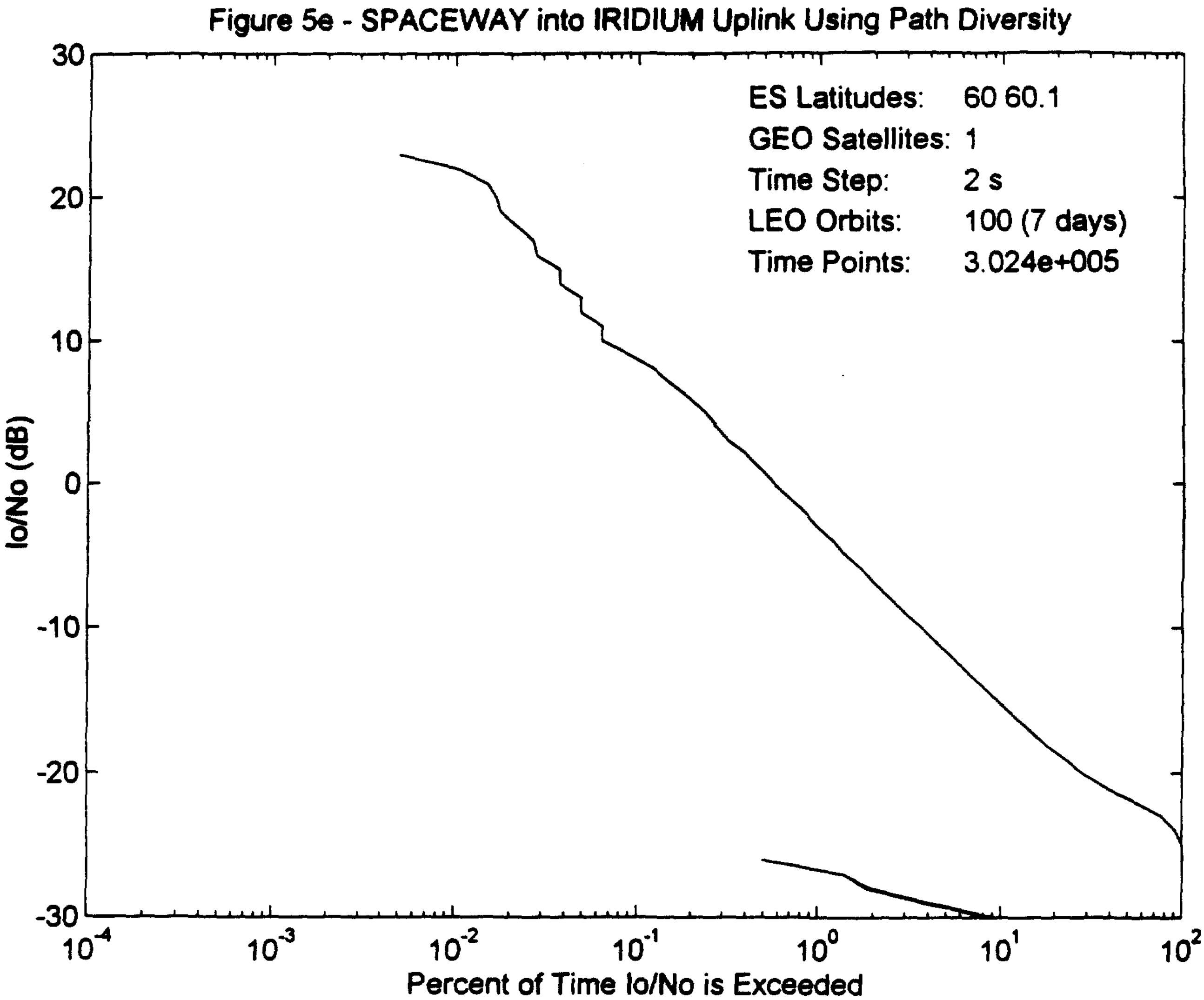


Figure 5e - SPACEWAY into IRIDIUM Uplink Using Path Diversity
ES Latitudes: 60 60.1
GEO Satellites: 1
Time Step: 2 s
LEO Orbits: 100 (7 days)
Time Points: 3.024e+005
Io/No (dB)
30
20
10
0
-10
-20
-30
10^-4
10^-3
10^-2
10^-1
10^0
10^1
10^2
Percent of Time Io/No is Exceeded

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IWG 4 March 24, 1995

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Document Title: **Co-Directional Frequency Sharing Between NGSO MEO MSS Feederlinks and GSO Satellite System Service and Feederlinks Operating in the 30/20 GHz Band**

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Purpose/Objective:

To provide preliminary analysis and simulation results related to the feasibility of co-directional frequency sharing between NGSO MSS feederlinks and GSO satellite systems service and feederlinks in the 30/20 GHz band.

Abstract:

Non-geostationary satellites are in continuous motion with respect to geostationary satellites. This gives rise to a number of short duration "in-line" interference events for both the Non-GSO and GSO networks when the Non-GSO satellite passes through the main beam of a geostationary satellite. The duration and the level of interference of such in-line interference events will be different for each Non-GSO system. The questions of characterizing these in-line interference events and examining the interference levels with respect to established criteria for acceptable interference are examined in this preliminary study.

This paper presents the preliminary results of a computer simulation of the worst-case, single-entry in-line interference events of an example NGSO-MEO satellite system and a GSO FSS satellite system in the 30/20 GHz band. Particularly, the interference between the MSS feederlinks of the NGSO-MEO system and the FSS service and feederlinks of the GSO system are characterized. Eight cases were examined between the two systems with earth stations placed at each of two different latitudes. Simulation results were then examined to determine which interference reduction mechanisms might help mitigate the severity of these in-line interference events such that codirectional frequency sharing is possible.

Fact Sheet Preparer: John Zuzek

Co-Directional Frequency Sharing Between NGSO MEO MSS Feederlinks and GSO Satellite System Service and Feederlinks Operating in the 30/20 GHz Band

1.0 Introduction

The Informal Working Group 4 (IWG-4) of the FCC Industry Advisory Committee for the 1995 World Radio Conference (WRC-95) has been looking at the potential for co-directional frequency sharing between NGSO MSS feederlinks and various FSS satellite systems. This paper presents preliminary analysis and results examining feasibility of co-directional frequency sharing between one particular example of an NGSO MSS system and its feederlinks and a typical GSO FSS system in the 30/20 GHz band. Previous studies have examined co-directional frequency sharing between NGSO MSS feederlinks and NGSO satellite systems. Other ongoing efforts seek to examine the feasibility of co-directional frequency sharing between various low earth orbiting NGSO systems' feederlinks with GSO FSS systems. In this study, a medium earth orbiting satellite system was chosen as the NGSO system to be examined as such a system has several different characteristics from its low earth orbiting counterparts that merit examination.

The NGSO system used in the analysis is designated as LEO B Non-GSO/MSS in Table 2.1.1 of the Task Group 4/5 Contribution to the Consolidated CPM Report to the WRC-95. It is a medium earth orbit constellation with a total of 12 satellites, using 4 satellites in each of 3 orbit planes at an orbital height of 10,355 km. With the limited number of satellites, the significantly higher altitude when compared with other NGSO systems, and the subsequently longer dwell times of the satellites for possible "in-line" interference events, this MEO NGSO system provides a very different set of parameters for investigation into the co-directional frequency sharing issue. The selected example Ka-band GSO FSS system is that which is described in detail in Document 4A/55-E, 4-5/93-E dated 10 November 1994. The satellites use both narrow spot beams and wider 3 degree beams for a variety of communications services. Simulation results of these systems and their interactions in "in-line" interference events provides valuable information into the feasibility of co-directional frequency sharing between these types of systems at 30/20 GHz.

2.0 Technical Characteristics of Satellite Systems

The orbital characteristics of the MEO NGSO satellite system examined in this study are given in Table 2.1. This system is a proposed non-geostationary orbit constellation comprised of a total of 12 satellites in circular medium earth orbit at an altitude of 10,355 km. These satellites are in 4 orbit planes at an inclination of 50 degrees. The GSO FSS satellite system uses 9 satellites in geostationary orbit in five different orbital locations spaced around the globe for Phase 1 of its deployed global network as is shown in Table 2.1. The necessary satellite and earth station/feederlink parameters are given in Tables 2.2 through 2.5.

Table 2.1 - Orbital Parameters

Parameter	LEO B (MEO MSS)	GSO FSS
Shape of Orbit	Circular	Circular
Height (km)	10,355	35,786
Inclination Angle	50°	0°
No. Of Satellites per Plane	4	-
Orbital Planes	3	1
Satellite Separation in Plane	90°	-
Satellite Phasing Between Planes	30°	-
Total Number of Satellites	12	9
Satellite Locations	-	25°E, 50°W, 101°W, 175°E, 110°E

Table 2.2 - GSO FSS Satellite Parameters

Receive Parameters	Narrow Spot Beam	Wide Spot Beam	Comment
Receive Frequency (GHz)	29.5 GHz	29.5 GHz	
Satellite Receive Antenna Gain (dBi)	46.5 (41.5 EOC)	35 (30 EOC)	EOC=Edge of Coverage
Receive System Noise Temp. (dB-K)	27.6	27.6	575.44 °K
Receive G/T (dB/K)	18.9 (13.9 EOC)	7.4 (2.4 EOC)	
Receive Channel Bandwidth (kHz)	500 kHz	500 kHz	384 kbps user data rate
Receive Polarization	RHC/LHC	RHC/LHC	
Transmit Parameters			
Transmit Frequency (GHz)	19.5 GHz	19.5 GHz	
Transmit Power per beam (dBW)	13.01 (20W)	17.78 (60W)	Each beam carries a 92 Mbps QPSK modulated TDM data stream
Transmit Line Loss (dB)	0.5	0.5	
Satellite Xmit Peak Antenna Gain (dBi)	46.5 (41.5 EOC)	35 (30 EOC)	
Satellite Xmit Peak EIRP (dBW)	59.01 (54 EOC)	52.3 (47.3 EOC)	
Satellite Xmit Signal Bandwidth (MHZ)	120 MHZ	120 MHZ	92 Mbps TDM data channel
Satellite Xmit Signal Polarization	RHC/LHC	RHC/LHC	

Table 2.3 - MSS MEO (LEO B) Satellite Parameters

Receive Parameters	**Value**	**Comment**
Receive Frequency (GHz)	29.5 GHz	
Satellite Receive Peak Antenna Gain (dBi)	38.8	3 separately steerable dual-band Ka-band antennas
Receive System Noise Temp. (dB-K)	32.62	1828.1 K
Receive G/T (dB/K)	6.18	
Receive Channel Bandwidth (MHZ)	2.5 MHZ	Feederlink channel is single 300 MHZ FDM signal composed of 108 2.5 MHZ sub-band channels
Receive Polarization	LHC	
Transmit Parameters		
Transmit Frequency (GHz)	19.5 GHz	
Transmit Power per channel (dBW)	1.3 (1.35W)	
Transmit Line Loss (dB)	0.5	
Satellite Xmit Peak Antenna Gain (dBi)	35.77	3 steerable dual-band antennas
Satellite Xmit Peak EIRP (dBW)	36.57	
Satellite Xmit Channel Bandwidth (MHZ)	2.5 MHZ	sub-band of 300 MHZ FDM signal
Satellite Xmit Signal Polarization	RHC	

Table 2.4 - GSO FSS Earth Station Parameters

Receive Parameters	**Narrow Spot Beam**	**Wide Spot Beam**	**Comment**
Receive Frequency (GHz)	19.5 GHz	19.5 GHz	
E/S Antenna Diameter (meters)	0.66 (26 inch)	2 (6.6 feet)	
E/S Receive Peak Antenna Gain (dBi)	42.96	51.81	
Receive System Noise Temp. (dB-K)	24.4 (275.4 K)	24.4	26.59 dB-K in rain
Receive G/T (dB/K)	18.56	27.41	16.37, 25.22 in rain
Receive Channel Bandwidth (MHZ)	120 MHZ	120 MHZ	92 Mbps TDM data;QPSK
Receive Polarization	RHC/LHC	RHC/LHC	

Table 2.4 (Continued) - GSO FSS Earth Station Parameters

Transmit Parameters	**Spot Beam**	**Narrow Beam**	**Comment**
Transmit Frequency (GHz)	29.5 GHz	29.5 GHz	
Antenna Size (m)	0.66 m	2 m	
E/S Xmit Power for 384 kbps service	-3.01dBW (.5W)	3.01 dBW (2W)	
Transmit Line Loss (dB)	0.5	0.5	
E/S Xmit Peak Antenna Gain (dBi)	44.45	53.30	
E/S Xmit Peak EIRP (dBW)	40.94	55.81	
E/S Xmit Signal Bandwidth (kHz)	500 kHz	500 kHz	384 kbps data ; QPSK mod
E/S Xmit Signal Polarization	RHC/LHC	RHC/LHC	

Table 2.5 - MSS MEO (LEO B) Feederlink Earth Station Parameters

Receive Parameters	**Value**	**Comment**
Receive Frequency (GHz)	19.5 GHz	
Feederlink E/S Antenna Size (meters)	7 meters (23 ft)	
E/S Receive Peak Antenna Gain (dBi)	60.8	
Receive System Noise Temp. (dB-K)	26.17	414 K
Receive G/T (dB/K)	34.63	
Receive Channel Bandwidth (MHZ)	2.5 MHZ	Feederlink channel is single 300 MHZ FDM signal composed of 108 2.5 MHZ sub-band channels
Receive Polarization	RHC	
Transmit Parameters		
Transmit Frequency (GHz)	29.5 GHz	
Transmit Power per channel (dBW)	3.01 (2W)	Power per 2.5 MHZ channel
Transmit Line Loss (dB)	0.5	
E/S Xmit Peak Antenna Gain (dBi)	64.8	7-meter antenna diameter
E/S Xmit Peak EIRP (dBW)	67.31	
E/S Xmit Channel Bandwidth (MHZ)	2.5 MHZ	sub-band of 300 MHZ FDM signal
E/S Xmit Signal Polarization	LHC	

3.0 Interference Analysis

Non-geostationary satellites are in continuous motion with respect to geostationary satellites. This time-varying geometry gives rise to a number of short duration "in-line" interference events for both the Non-GSO and GSO networks. The in-line interference event will occur whenever the Non-GSO satellite passes through the main beam of a given geostationary satellite. The duration and the level of interference of such in-line interference events will be different for each Non-GSO system. The LEO B or medium earth orbit satellite system examined in this analysis is further characterized by a much higher altitude and subsequently a much longer dwell time for these in-line events than with the NGSO LEO satellites. Throughout the discussion and results, the LEO B system is referred to as the MEO MSS system.

A computer simulation of the worst-case, single-entry, in-line interference events of the MEO MSS satellite system and a GSO FSS satellite system in the 30/20 GHz band was performed. Particularly, the interference between the MSS feederlinks of the MEO MSS system and the FSS service and feederlinks of the GSO system are characterized. A worst case scenario is assumed in which the GSO FSS user terminal and the MEO MSS feederlink earth station are essentially co-located. At some time during its orbit, a MEO MSS spacecraft appears along the line of sight (LOS) between the GSO FSS user terminal and the GSO FSS spacecraft. Conversely, an analogous case occurs when the GSO FSS spacecraft appears directly behind the MEO MSS spacecraft and is in the main beam of the MEO MSS feederlink earth station. Four possible interference situations were considered separately:

(1) one MEO MSS feederlink earth station interfering with a GEO FSS satellite;
(2) one GSO FSS earth station interfering with a MEO MSS satellite;
(3) one MEO MSS satellite interfering with a GEO FSS earth station; and
(4) one GSO FSS satellite interfering with the MEO MSS earth station.

Each of these possible interference situations was examined for both a narrow 1 degree spot beam on the GSO FSS satellite as well as a wider 3 degree beam. Additionally, all eight of these interference cases was examined with the co-located earth stations located at two different latitudes: a medium latitude of 34° North and a high latitude of 45° North.

Due to the time-varying and intermittent nature of these in-line interference events, some sort of criteria for assessing the severity of these events was needed other than the standard carrier-to-interference ratio (C/I). A criteria for acceptable interference based on an allowable interference-to-noise ratio (I/N_T) for a given percentage of time was utilized as presented in the CPM Report to WRC-95, Chapter 2, Section I, Part C, Subsection 3.1.2, "Criteria for Acceptable Interference". For 20-30 GHZ networks, these values are as follows:

Interference	Maximum % Time Exceeded
Negligible	0.87
$0.78N_T$	0.119
$2.98N_T$	0.0294
$14.8N_T$	0.0004

Note that for the "Negligible" entry corresponding to 0.87% of the time, an I/N_T of 0.06 (or -12.2 dB) was used for calculation purposes. In addition to these limits, and regardless of whether these limits are met, interference that exceeds the $14.8N_T$ criterion may not occur more than once in any 14 day period. These criteria are to be used for Non-GSO/MSS feederlinks interfering with GSO/FSS networks. For the GSO/FSS networks interfering with the Non-GSO/MSS feederlinks, the same set of criteria was assumed to be applicable.

The computer simulations of the MEO MSS versus GSO FSS systems were performed using standard antenna patterns and the system parameters given in section 2 of this paper. The algorithms implementing the engineering equations that describe these interference events were developed using the Mathcad® computer package on a DOS/Windows-based personal computer. The MEO MSS satellite system was simulated over a 24 hour period as it has a repeating ground track over that period of time. Additionally, this period was divided into equal 2 second time intervals to simulate the interference events. As the dwell time of the MEO MSS satellites is rather lengthy in comparison to the many LEO NGSO satellite systems (i.e., the MEO MSS satellites move across the sky at a significantly slower rate), this time interval should be more than sufficient to capture the peak interference levels and to adequately characterize the in-line interference events.

The antenna patterns used in this analysis are given in Appendix A to this report. The off-axis antenna gain pattern used for the satellite antennas is that which is described in ITU-R Report 558-3. The earth station off-axis antenna patterns correspond to the pattern presented in Appendix 29, Annex III of the Radio Regulations.

4.0 Interference Analysis Results

The results of the interference analysis are presented in Tables 4.1 through 4.9 and Figures 4.1 through 4.4. Tables 4.1 through 4.8 summarize the percentage of time that the permissible I/N_T is exceeded for each interference case and show the maximum continuous time in minutes that the particular interference level is exceeded on each of the four interference paths. The shaded blocks in Tables 4.1, 4.3, 4.5, and 4.7 show those cases where the I/N_T criterion was not met for each interference scenario. Table 4.9

shows the peak values of the I/N_T ratios in dB experienced on each of the four interference paths for each latitude and GSO FSS spot beam size. The values in parentheses show the amount by which the allowable I/N_T was exceeded for each case.

Table 4.1 - Percent Time Interference Level Is Exceeded For 34° N Latitude and Narrow Spot Beams on the GSO Spacecraft

Interference Level (fraction of N_T)	Max Allowed % Time	GEO S/C Receiver	MEO S/C Receiver	GEO E/S Receiver	MEO E/S Receiver
$I=.06*N_T$	0.87%	0.535	0.585	1.150	0.454
$I=0.78*N_T$	0.119%	0.192	0.199	0.412	0.162
$I=2.98*N_T$	0.0294%	0.111	0.116	0.206	0.095
$I=14.8*N_T$	0.0004%	0.060	0.069	0.153	0.051

Table 4.2 - Maximum Continuous Time (In Minutes) That Interference Level Is Exceeded For 34° N Latitude and Narrow Spot Beams on the GSO Spacecraft

Interference Level (fraction of N_T)	GEO S/C Receiver	MEO S/C Receiver	GEO E/S Receiver	MEO E/S Receiver
$I=.06*N_T$	7.70	8.03	16.57	6.53
$I=0.78*N_T$	2.77	2.87	5.93	2.33
$I=2.98*N_T$	1.60	1.67	2.97	1.36
$I=14.8*N_T$	0.87	1.00	2.20	0.73

Table 4.3 - Percent Time Interference Level Is Exceeded For 45° N Latitude and Narrow Spot Beams on the GSO Spacecraft

Interference Level (fraction of N_T)	Max Allowed % Time	GEO S/C Receiver	MEO S/C Receiver	GEO E/S Receiver	MEO E/S Receiver
$I=.06*N_T$	0.87%	0.565	0.569	1.183	0.479
$I=0.78*N_T$	0.119%	0.201	0.206	0.424	0.174
$I=2.98*N_T$	0.0294%	0.118	0.118	0.218	0.100
$I=14.8*N_T$	0.0004%	0.063	0.072	0.160	0.053

Table 4.4 - Maximum Continuous Time (In Minutes) That Interference Level Is Exceeded For 45° N Latitude and Narrow Spot Beams on the GSO Spacecraft

Interference Level (fraction of N_T)	GEO S/C Receiver	MEO S/C Receiver	GEO E/S Receiver	MEO E/S Receiver
$I=.06*N_T$	8.13	8.20	17.03	6.90
$I=0.78*N_T$	2.90	2.97	6.10	2.50
$I=2.98*N_T$	1.70	1.70	3.13	1.43
$I=14.8*N_T$	0.90	1.03	2.30	0.77

Table 4.5 - Percent Time Interference Level Is Exceeded For 34° N Latitude and Wide Spot Beams on the GSO Spacecraft

Interference Level (fraction of N_T)	Max Allowed % Time	GEO S/C Receiver	MEO S/C Receiver	GEO E/S Receiver	MEO E/S Receiver
$I=.06*N_T$	0.87%	0.185	0.815	0.822	0.243
$I=0.78*N_T$	0.119%	0.065	0.292	0.296	0.088
$I=2.98*N_T$	0.0294%	0.037	0.171	0.171	0.051
$I=14.8*N_T$	0.0004%	0.014	0.090	0.072	0.019

Table 4.6 - Maximum Continuous Time (In Minutes) That Interference Level Is Exceeded For 34° N Latitude and Wide Spot Beams on the GSO Spacecraft

Interference Level (fraction of N_T)	GEO S/C Receiver	MEO S/C Receiver	GEO E/S Receiver	MEO E/S Receiver
$I=.06*N_T$	2.67	11.73	11.83	3.50
$I=0.78*N_T$	0.93	4.20	4.27	1.27
$I=2.98*N_T$	0.53	2.47	2.47	0.73
$I=14.8*N_T$	0.20	1.30	1.03	0.27

Table 4.7 - Percent Time Interference Level Is Exceeded For 45° N Latitude and Wide Spot Beams on the GSO Spacecraft

Interference Level (fraction of N_T)	Max Allowed % Time	GEO S/C Receiver	MEO S/C Receiver	GEO E/S Receiver	MEO E/S Receiver
$I=.06*N_T$	0.87%	0.197	0.836	0.843	0.259
$I=0.78*N_T$	0.119%	0.072	0.299	0.303	0.093
$I=2.98*N_T$	0.0294%	0.039	0.174	0.178	0.053
$I=14.8*N_T$	0.0004%	0.016	0.093	0.076	0.021

Table 4.8 - Maximum Continuous Time (In Minutes) That Interference Level Is Exceeded For 45° N Latitude and Wide Spot Beams on the GSO Spacecraft

Interference Level (fraction of N_T)	GEO S/C Receiver	MEO S/C Receiver	GEO E/S Receiver	MEO E/S Receiver
$I=.06*N_T$	2.83	12.03	12.13	3.73
$I=0.78*N_T$	1.03	4.30	4.37	1.33
$I=2.98*N_T$	0.56	2.50	2.57	0.77
$I=14.8*N_T$	0.23	1.33	1.10	0.30

Table 4.9 - Peak I/N_T (in dB) Experienced For Each Interference Case

Latitude	Beam Size	GSO S/C Receiver	MEO S/C Receiver	GSO E/S Receiver	MEO E/S Receiver
34° N	Narrow Spot	37.4 (25.7)	15.8 (4.1)	20.4 (8.7)	31.7 (20.0)
45° N	Narrow Spot	37.4 (25.7)	15.3 (3.6)	19.9 (8.2)	31.6 (19.9)
34° N	Wide Spot	25.9 (14.2)	30.7 (19.0)	29.3 (17.6)	24.9 (13.2)
45° N	Wide Spot	25.9 (14.2)	30.2 (18.5)	28.8 (17.1)	24.9 (13.2)

For the cases where the earth stations are co-located at 34° N, the peak in-line interference event occurs when the MEO MSS spacecraft is at a sublatitude of 8.51° N. When the two earth stations are co-located at 45° N, the peak in-line interference event occurs when the MEO MSS spacecraft is at a sublatitude of 10.61° N.

Looking at Tables 4.1-4.8, it is obvious that the cases involving the narrow spot beams from the GSO FSS satellite are worse, in general, than those cases involving the wide spot beams on the GSO FSS satellite when interference into the GSO satellite receiver and interference into the MEO MSS earth station receiver are considered. The converse is true for the cases involving the wide spot beams on the GSO FSS satellite, where the interference into the MEO MSS satellite receiver and the GSO FSS earth station receiver are worst. This appears to be true regardless of earth station latitude. For the higher latitude cases, the peak values of the interference events are somewhat (almost negligibly) smaller while the percent time the interference level is exceeded rises slightly. Thus, the effects of earth station latitude are negligible.

In addition to the tables, Figures 4.1-4.4 show graphically the worst case interference scenario into the GSO FSS satellite receiver for each of the possible latitude/spot beam combinations. Note that these graphs are shown in dB and depict only the **worst 2 minute time interval** in a given 24 hour period. Thus, the line corresponding to the -12.2 dB and -1.1 dB criteria appear to be exceeded 100% of the time, which they are in this 2 minute interval, but clearly are not for the 24 hour period in question.

5.0 Interference Mitigation

Earlier analyses and computer simulation results described in the document showed that very high levels of interference can occur between the non-GEO medium earth orbit (MEO) MSS system and a GEO FSS system if they share the same frequencies in the 30/20 GHz band. For example, during an "in-line" interference event in which the mainbeam of a tracking MSS feederlink station is momentarily pointed directly into the mainbeam of a GSO satellite as a result of tracking a moving MEO satellite, uplink interference from the feederlink station at the GSO satellite receiver can exceed the maximum allowable value by almost 26 dB for about a minute. Interference on other interference paths is also unacceptably high, both in terms of peak value and duration as indicated in Tables 4.1-4.9.

To mitigate the interference, several methods were considered. For example, to solve the problem of MSS feederlink interference into the GSO satellite receiver on the uplink, one might consider creating an exclusion zone around the MSS feederlink terminal and avoid pointing the mainbeam of the GSO satellite spot beam anywhere within this exclusion zone (i.e., use the discrimination of the GSO satellite antenna to achieve the necessary isolation). Unfortunately, the interference from the feederlink terminal is so high in this case that 26 dB of discrimination is needed from the GSO satellite antenna. This translates into an exclusion zone around the MSS feederlink earth station which is *nearly as large as the U.S. itself*. This is indicated by the -25.7 dB gain contour of the GSO